to the south; it is from 4000 to 4600 feet above sea-level. Nearly the whole of it is magnificently watered by a network of running streams, the springs supplying which well out from the highest portions of the downs, so that an enormous area of land could be put under irrigation. The whole year round a cool wind blows almost continuously from the south-east, a wind which in the winter months becomes so cold that it may well have its origin among the icebergs of the Antarctic seas. The country, Mr. Selous assures us from his own experience, is admirably adapted for European occupation and labour. The soil is rich and fertile, and from the facilities for irrigation enormous quantities of wheat could be grown. Although the highest and healthiest parts of the country are very open, still one is never out of sight of patches of trees. Besides the high plateau of Mashonaland, the whole of which is over 4000 feet above sea-level, extending along the watershed for a distance of over 200 miles from the Matabele country to the source of the Hanyane and Mazoe Rivers, with a breadth of from sixty to one hundred miles, there is a vast extent of country lying to the south, east, and north-east of the plateau, well-watered and fertile, having an altitude of from 3000 to 4000 feet. These plateaus are of much ethnological interest, as giving shelter to the very few remnants of the peaceful Mashonas that have escaped extermination at the hands of the bloodthirsty intruders, the Matabele.

MR. SELOUS leaves England for the Cape to-morrow. It is possible that he may be compelled to lead a prospecting party up the Zambesi. Should this not be the case, he is likely to proceed northwards beyond the Zambesi to the Garenganze country, west of Lake Bangweolo, and thence make either for the source of the Lualaba, which he will endeavour to follow down until it broadens out into the Congo.

M. J. TAUPIN, Professor in the College of Interpreters at Saïgon, has completed an important exploration in the lower Laos country. Starting from Saïgon in October 1887, M. Taupin, after visiting the Siamese province of Siem-Reap, and photographing the numerous Khmer remains in that province, notably those of Angkor, crossed the forests of the lower Laos, to Ubon, where he resided several months. Among other things he has obtained a knowledge, at least summary, of the Laotian language and writing, the only graphic-alphabetic system, it is stated, on which we have no positive information. The language, M. Taupin states, is spoken by four million people. He has surveyed about 1000 kilometres of rivers and watercourses not found on any map, besides making many important corrections. He has made many notes on natural history, and experimented with the culture of European plants. The meteorology and anthropology of the country, moreover, received much attention at his hands.

AT the next meeting of the Geographical Society, on May 13, the evening will be mainly occupied with a discussion of Mr. Stanley's letters, in which several well-known African authorities are likely to take part.

CAPTAIN BINGER, a French explorer, has succeeded in filling up one of the blanks on the map of Africa. Starting from the banks of the Niger, he penetrated the country of Kong, amid many dangers and sufferings.

THE HENRY DRAPER MEMORIAL.[1]

THE researches which constitute the Henry Draper Memorial have consisted for the last three years in the photographic study of the spectra of the stars. While this subject will continue to be the principal one under investigation, Mrs. Draper has decided to extend the field of work undertaken, so as to include the study of the other physical properties of the stars by photography. As will be seen from the detailed statement below, the first research undertaken is now rapidly approaching completion, the plans for the study of the southern stars have been matured, and this study will soon be begun; the detailed study of the spectra of the brighter stars is making progress, and a large piece of photometric work will soon be undertaken with a new telescope. The progress made in each investigation will now be described, as in previous Reports.

1. *Catalogue of Spectra of Bright Stars.*—The Bache telescope, which has an 8-inch photographic doublet as an objective, is used for this work. The photographs cover the entire sky north of −25°, with exposures of about five or ten minutes. About 28,000 spectra of 10,800 stars have been examined, including nearly all stars visible in Cambridge of the seventh magnitude or brighter. The Catalogue is now nearly ready for the printer, the final copy having been prepared as far as 14h. in right ascension.

Nearly the entire time of three or four computers has been devoted during the past year to this work. The intensity of about 15,000 of the spectra has been measured, completing this part of the research. Much time has been spent in checking and verifying the results. All the positions have been checked and brought forward to 1900 two or more times independently. All discordant measures have been re-examined, and a search has been made for possible error when bright stars are omitted or very faint ones inserted. Seven thousand two hundred notes have been made on the various stars in the Catalogue. Each note has an appropriate number which permits it to be entered in its proper place. Most of these notes relate to additional lines contained in these spectra besides those by which the type is determined. The position and intensity of these lines is estimated. A portion of them have been reduced to wavelengths. The printing of the Catalogue might have been already begun but for the difficulty of deciding how the different types of spectra should be distinguished. The classification used for visual observations fails to indicate many differences obvious in the photographs. On the other hand, the photographic portions of spectra of Types II. and III. are nearly identical. The photographs also show many stars whose spectra are intermediate between those of the typical stars which have determined the usual classification. A system has, however, been adopted which permits all differences detected in the photographs to be described in the printed volume.

Thirteen spectra were found on these plates which could not be identified with stars. Three of these proved to be due to Mars, one to Vesta, three to Jupiter, four to Saturn, and two to Uranus. Accordingly all the exterior planets bright enough to be detected in this way appear on these plates.

The measures of the intensity of the spectra form a very important portion of this work. Since the same part of the spectrum is measured in each case, the true relative energy is determined. That is, the same result is obtained as if the measures of rays of the same wave-length were made by any other method, as photometrically by the eye, by the thermopile, or by the bolometer. The colour of the star will be indicated by the extent of the spectrum, which is also noted. For the first time, therefore, we shall have a photometric Catalogue in which the error due to the colour of the star is eliminated. A preliminary determination of the accordance of the results derived from different photographs of the same star shows that the average value of the residuals will be about 0·16, which is the same as the corresponding quantity for the Harvard Photometry. The number of stars is more than twice that contained in the latter Catalogue.

2. *Catalogue of Spectra of Faint Stars.*—In November 1888, the photographs required to cover the sky north of the equator were nearly finished. It was expected that in two months the observations would be completed. The telescope, which was the same as that used in the previous research, was, however, wanted for photographing the Solar Eclipse of January 1, 1889. It was accordingly sent to Willows, California, where it was mounted, and the greater portion of the remaining photographs were taken there. It was then sent to Peru, as will be described below. The few remaining photographs, including the repetition of those found on further examination to be unsatisfactory, will be taken in Peru.

3. *Detailed Study of the Spectra of the Brighter Stars.*—The 11-inch refractor with one, two, or four large prisms over its objective has been employed in this work throughout nearly every clear night, until stopped by the morning twilight; 686 photographs have been taken, most of them with an exposure of two hours. With our present photographic plates about 570 stars north of −30° are bright enough to be photographed with one prism, 170 of them with two prisms, and 87 of them with four prisms. To obtain the best possible result some of the photographs must be repeated many times. The difficulty is increased by the invariably hazy appearance of the lines in some spectra, like that of α Aquilæ, which was at first attributed to poor definition of the photograph. It is expected that the work will be completed during the next year by original or repeated photographs of 228 stars with one prism, of 64 with two, and of 12 with four. In general, stars as bright as the

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[1] "Third Annual Report of the Photographic Study of Stellar Spectra conducted at the Harvard College Observatory," Edward C. Pickering, Director. (Cambridge: John Wilson and Son, University Press, 1889.)

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fourth magnitude can be satisfactorily photographed with one prism, the spectra obtained being about an inch long. Fainter stars, if of a bluish colour, give sufficiently distinct images, in some cases good results being obtained with stars of the seventh magnitude. For example, fourteen stars in the Pleiades are well photographed with this apparatus. With four prisms much longer spectra are obtained and many more lines are visible. But certain differences in the character of the spectra are better shown with the smaller dispersion. Numerous photographs have been taken of the variable stars *o* Ceti and β Lyræ. The changes in the spectrum of the latter star seem to be undoubted, those of *o* Ceti, if any, to be slight. Various peculiarities in the spectra of individual stars have been detected. One photograph of ζ Ursæ Majoris shows the K line distinctly double, and others show it single. Many photographs will be required to determine the law of its variation, if this is due to changes in the star itself. Bright lines were detected in the spectrum of φ Persei, putting it in a class in which only two or three other stars are known to fall. In the double star β Cygni the two components have spectra of different types, an important consideration in the theories regarding their formation. The brighter component is of the second type, the fainter of the first.

Ordinary photographic plates are not sensitive to rays of much greater wave-length than the F line, or 486. By staining the plates with various coal-tar products the range of sensitiveness may be greatly extended. With erythrosin the spectrum extends to the wave-length 590. The sodium line D is distinctly seen to be double in the photographs of α Boötis and α Aurigæ. Various experiments were also made with cyanin, but the plates were not sufficiently sensitive to give good results. The entire length of the spectrum with four prisms, including the portion obtained by erythrosin, is about six inches and a half.

A beginning has been made of the measures of the positions of the lines in the spectrum. A scale of fortieths of an inch has been ruled on glass, and the positions of the lines read off with the aid of a magnifying-glass. Twelve of the photographs of α Canis Majoris have been studied in this way. The spectrum of this star is traversed by the hydrogen lines, which are strong, and by other lines which are so faint that they are only visible when the dispersion is large and the definition good. The catalogue thus formed contains about 320 lines. The average deviation of the measures of the same line on different plates is about 0·05 of a millionth of a millimetre, or 0·05 cm. on the scale of Ångström's map. If the line occurs in the solar spectrum these measures will generally identify it. In other cases the exact position must be determined by a dividing engine. If a line can be distinctly seen, its wave-length can probably be thus determined with as great accuracy as that of the position of the solar lines on the map of Ångström. In the spectrum of α Boötis 140 lines are visible between the D and F lines.

The classification of this large number of spectra is a matter of no little difficulty. Slight differences exist in many stars, and certain stars appear to hold an intermediate position, so as to render a rigorous division into classes impossible. On the other hand, many stars appear to have identical spectra. The first step will be to arrange the stars in groups, and then compare the best defined spectra of different groups. A minute discussion and the measurement of wave-lengths will be necessary only in the investigation of a comparatively small number of spectra.

4. *Faint Stellar Spectra.*—The 28-inch reflecting telescope constructed by Dr. Draper was assigned to this work. During the first six months of the year a careful study was made of this problem, and the difficulties encountered bore evidence of the skill of Dr. Draper in obtaining good results with this telescope. The best method of using this instrument seemed to be a modification of the form first tried by Dr. Draper,—a slit spectroscope from which the slit had been removed. The rays from the mirror were rendered parallel by a concave lens which replaced the objective of the collimator. As this lens had the same focal distance as the objective of the observing telescope, it was not necessary that either should be achromatic. After long trials with this and other forms of apparatus, a spectrum was at length obtained showing good definition. As the results were not better than those described above, and the instrument, from its size, was slow in operation, the experiments have not been carried further.

5. *Catalogue of Spectra of Bright Southern Stars.*—The 8-inch Bache telescope remained in California until February 2, 1889, and was then sent to Peru to continue research No. 1 on the southern stars. The sky from −25° to the south pole will be covered, and the resulting photographs sent to Cambridge and reduced, as in the case of the northern stars. The advantages of discussing all stars from the north to the south pole according to one system are very great, and are here secured for the first time in so extensive an investigation. If no unforeseen difficulty arises, the photographs will all be completed during the next two years.

6. *Catalogue of Spectra of Faint Southern Stars.*—Research No. 2 will also be extended to the south pole simultaneously with the observations required for No. 5. It is expected that these photographs also will be completed in two years.

The Bache telescope described above has proved an extremely convenient instrument for various purposes. Besides the spectroscopic researches already mentioned, several other investigations have been undertaken with it, some of which will be found in the Memoirs of the American Academy, vol. xi. p. 179, and the Harvard Observatory Annals, vol. xviii. Nos. iv., vi., and vii. Owing to its short focal length it possesses many advantages over photographic telescopes of the usual form. With exposures of an hour and a half more stars were photographed in the Pleiades than are given in the engraving accompanying the Annual Report of the Paris Observatory for 1886, although that work was based on photographs taken by the MM. Henry with exposures of three hours and a telescope having an aperture of 13 inches. Nearly twice as many stars were photographed in this region as were visible with the 15-inch telescope of the Harvard College Observatory. The short focus of the telescope also gives it especial advantages for photographing nebulæ. Twelve new nebulæ were thus discovered in a region where but eighteen were known before. Various other investigations, such as a determination of the law of atmospheric absorption, have been undertaken with the aid of this telescope. It has been so persistently used in spectroscopic work that the other researches have been neglected, especially those in which very long exposures were required. Its removal to Peru now cuts it off for some time from such use on the northern stars. Accordingly, Mrs. Draper has procured a similar lens, which is now in the hands of the firm of Alvan Clark and Sons for retouching and mounting. Several important researches will be undertaken with this instrument. Photography is now used in so many departments of astronomy that a general investigation of the photographic brightness of the stars seems desirable. A plan has been proposed by which a single plate will contain photographs of a number of regions one degree square, but in different portions of the sky. Thus a series of standard faint stars will be photographed, which can all be measured, and reduced to the same scale. One or more photographs of the vicinity of the north pole will be taken on each plate, and thus serve to correct the results obtained on different plates. It is proposed in this way to secure a series of standards of stellar magnitude at intervals of about five degrees. A third lens of similar form, having an aperture of four inches, will be attached to the telescope, with which photographs on a smaller scale, but five degrees square, will be taken simultaneously. These photographs will cover the entire sky, and it is proposed to measure the photographic brightness of all stars of the seventh magnitude, or brighter, which are represented on them. This investigation will have a special value in connection with the photometric measures of the spectra described above. It is hoped also to photograph the entire northern sky by means of the 8-inch telescope, with exposures of an hour. Each plate covers a region nearly ten degrees square, of which the images in the central five degrees square are satisfactorily in focus. One of the regions containing standard stars will appear in the centre of each plate. By such a series of plates the photographic brightness of any stars brighter than the fifteenth magnitude can be determined on a uniform scale. The faintest stars photographed will be nearly a magnitude fainter than the limit proposed by the Astrophotographic Congress, so that all plates included in that work can be reduced to a uniform system. The advantages of such plates for studies of the distribution of the stars and other similar investigations are obvious.

From the above description it appears that the field of work of the Henry Draper Memorial, as now extended, is almost boundless. The problems to be investigated relate to the fundamental laws regulating the formation of the stellar system. Questions of such importance should be discussed on a sufficiently large scale, or the results of the discussion will soon be superseded by a repetition of the work. The liberal provision made for the Henry Draper Memorial permits the investigations to be planned on a scale which is likely to avoid such undesirable duplication of work.

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